

DEVICE FOR PROCESSING A METAL SLAB, PLATE OR STRIP, AND PRODUCT PRODUCED USING THIS DEVICE

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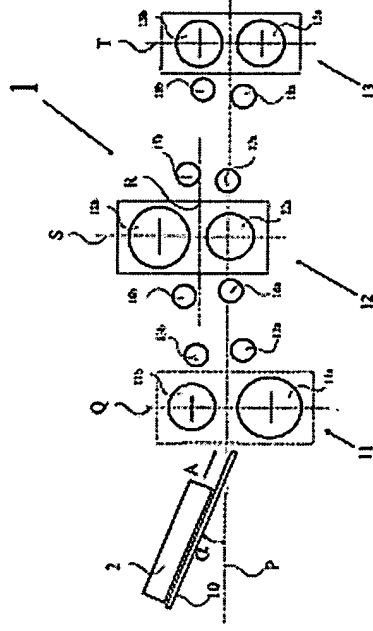
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Abstract of WO03018221

The invention relates to a device for processing a metal slab, plate or strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being designed to roll a metal slab, plate or strip between the rolls. According to a first aspect of the invention, the device is provided with feed means which are designed to guide the slab, plate or strip between the rolls at an angle of between 5 DEG and 45 DEG with respect to the perpendicular to the plane through the center axes of the rolls. According to a second aspect of the invention, the device is provided with one or more following rolling mill stands with driveable rolls, and the rolling mill stand and one or more following rolling mill stands are designed in such a manner that, during use, their rolls have different peripheral velocities, the difference in peripheral velocity amounting to at least 5% and at most 100%.



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(54) Title: DEVICE FOR PROCESSING A METAL SLAB, PLATE OR STRIP, AND PRODUCT PRODUCED USING THIS DEVICE

(57) Abstract: The invention relates to a device for processing a metal slab, plate or strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being designed to roll a metal slab, plate or strip between the rolls. According to a first aspect of the invention, the device is provided with feed means which are designed to guide the slab, plate or strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls. According to a second aspect of the invention, the device is provided with one or more following rolling mill stands with driveable rolls, and the rolling mill stand and one or more following rolling mill stands are designed in such a manner that, during use, their rolls have different peripheral velocities, the difference in peripheral velocity amounting to at least 5% and at most 100%.



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DEVICE FOR PROCESSING A METAL SLAB, PLATE OR STRIP, AND PRODUCT PRODUCED USING THIS DEVICE

5 The invention relates to a device for processing a metal slab, plate or strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being designed to roll a metal slab, plate or strip between the rolls.

10 A device of this type is known and is in very widespread use in the metal industry for reducing the thickness of a cast slab, plate or strip and for improving the mechanical properties of a slab, plate or strip. The rolling which is carried out using the device takes place during the processing of thick slabs and plates, usually at elevated temperature. During the rolling of thin plates and strips, the plate or strip is not raised to an elevated temperature prior to the rolling.

15 Working with the known device has the drawback that the improvements to the mechanical properties are produced primarily in the outermost layers of the rolled product and only to a lesser extent or not at all in the interior of the product. This is true in particular of thick slabs.

20 It is an object of the invention to provide a device for processing a metal slab, plate or strip with which the mechanical properties of the processed product can be improved.

It is another object of the invention to provide a device of this type which allows mechanical properties of the interior of a slab, plate or strip to be improved.

25 Yet another object of the invention is to provide a device of this type which is able to improve the mechanical properties in a simple way.

It is also an object of the invention to use the device according to the invention to provide improved metal slabs, plates and strips.

30 According to a first aspect of the invention, one or more of these objects are achieved by a device for processing a metal slab, plate or strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being designed to roll a metal slab, plate or strip between the rolls, which device is provided with feed means which are designed to guide the slab, plate or strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls.

Surprisingly, it has been found that by feeding a metal slab, plate or strip at an angle between the rolls of a rolling mill stand, shearing occurs over the entire thickness of the slab, plate or strip. This shearing is also more or less constant over the entire thickness.

5 Firstly, this allows grain refinement to occur over the entire thickness. During standard rolling, shearing and therefore grain refinement will only occur at the surfaces. Secondly, the shearing closes up pores in the metal which are usually formed during the casting of aluminum, for example. Therefore, using the device according to the invention closes up pores over the entire thickness of the material. Both effects are

10 important mainly for relatively thick material. The shearing also causes the eutectic particles which may be present in the material to be broken up, which results in an improved toughness. The feed means which are added to the device in accordance with the invention therefore results, in a simple manner, in an improvement to the material which it produces. Feeding a slab, plate or strip in at an angle also leads to the rolls

15 having an improved grip on the front of the material which is introduced, with the result that the reduction in thickness of the material does not have to be as great as in standard rolling, in which the material is introduced between the rolls at an angle of 0°. The feeding in at an angle also prevents or reduces the "refusal" of a slab, when the rolling mill stand does not take hold of the slab on account of the reduction being too

20 high.

In addition to rolling a slab, plate or strip made from a single metal or a single metal alloy, the device according to the invention can also be used to roll a slab, strip or plate comprising two or more layers of metal, in which case the metal layers may consist of

25 the same metal alloy, of different metal alloys or of different metals or metal alloys.

The feed means are preferably designed to introduce the slab, plate or strip between the rolls at an angle of between 10° and 25° with respect to the perpendicular to the plane through the center axes of the rolls, more preferably at an angle of between 15° and

30 25°, and even more preferably at an angle of substantially 20°. In the case of feeding at between 10° and 25° and preferably between 15° and 25°, the shearing is relatively great while the angle is not so great as to impede feed to the roll nip. In many cases, it has been found that the feeding can be carried out optimally at an angle of substantially

35 20°.

According to an advantageous embodiment of the device, the feed means comprise a feed surface or a roller table. This easily allows the material to be fed at an angle between the rolls. Other designs of the feed means are also possible.

The angle between the feed means and the rolling mill stand is preferably adjustable. This allows the angle to be adapted to the thickness of the slab, plate or strip as desired, for example if the thickness of the material means that a specific introduction angle is desirable. Then, if desired the further rolling using the device can be continued at a different angle.

To increase the degree of shearing, the rolling mill stand is preferably designed in such a manner that, during use, the rolls have different peripheral velocities, the difference in peripheral velocity amounting to at least 5% and at most 100%, and preferably at least 5% and at most 50%, more preferably at least 5% and at most 20%. The difference in peripheral velocity is partly determined by the thickness of the material; in addition, the shearing increases as the difference in peripheral velocity between the rolls becomes greater. Greater shearing is advantageous since it leads to greater grain refinement and improved closing up of the pores. On the other hand, if there is a high difference in velocity, there is a high risk of slipping between the rolls and the material, which would result in irregular shearing.

According to an advantageous embodiment, the rolls have a different diameter and/or can be driven at different rotational speeds. This makes it possible to obtain the difference in peripheral velocity.

The device is preferably provided with one or more following rolling mill stands with driveable rolls which are positioned downstream of the rolling mill stand, as seen in the rolling direction. This allows a slab, plate or strip to be subjected to a rolling operation two or more times without interruption, so that a desired result can be achieved more quickly using this device. Obviously, it is also possible for the material to be passed through the same device twice, but this takes more time, particularly when strip material is being rolled.

According to an advantageous embodiment, the device is designed, during use, to feed the metal slab, plate or strip to at least one of the one or more following rolling mill stands at an angle of between 5° and 45°, preferably at an angle of between 10° and 25° and more preferably between 15° and 25°, the angle preferably being adjustable. As a result, at these rolling mill stands the material is passed between the rolls at an angle, and therefore is subjected to shearing over the entire thickness at these rolling mill stands. The result of this is that the material undergoes considerable shearing in one pass through the device. The same benefits apply as for the rolling mill stand to which the material is fed first.

It is preferably also true of the following rolling mill stands that at least one of the one or more following rolling mill stands is designed in such a manner that, during use, the rolls have a different peripheral velocity, in which case the rolls preferably have a different diameter and/or can be driven at different rotational speeds. By also providing the rolls of the following rolling mill stands with a different peripheral velocity, the shearing which is imparted to the material as it passes through the device is increased further. The same statements apply here as those made in connection with the difference in velocity between the rolls of the first rolling mill stand through which the material is passed.

According to a preferred embodiment, at least one of the one or more following rolling mill stands has a roll nip which is situated outside the plane of symmetry of the roll nip of the rolling mill stand. As a result, it is easy for the material to be passed at an angle to said following rolling mill stand.

It is preferable for support rolls to be arranged upstream of the one or more following rolling mill stands, as seen in the direction of rolling, in order to support and/or guide the metal slab, plate or strip. These support rolls can feed the material to the following rolling mill stands, for example, at the desired angle.

According to a preferred embodiment of a device without following rolling mill stands, the device is provided on both sides with feed means which are designed to pass the slab, plate or strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls, preferably at an angle of between 10° and 25° , the angle between the feed means being adjustable between 0 and 45° and it being possible for the rolls to be driven in both directions of rotation. With the aid of this device, it is possible for material to be passed back and forth through the device, and each time the material can be supplied at an angle of between 5 and 45° and preferably between 10° and 25° and can be guided out of the device at an angle of 0° .

According to a second aspect of the invention, one or more of the abovementioned objects is achieved by a device for processing a metal strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being designed to roll the metal strip between the rolls, which device is provided with one or more following rolling mill stands with driveable rolls, and in that the rolling mill stand and one or more following rolling mill stands are designed in such a manner that, during

use, their rolls have different peripheral velocities, the difference in peripheral velocity amounting to at least 5% and at most 100%.

5 In this device, therefore, the material is passed through two or more rolling mill stands, the rolls of each rolling mill stand in each case having a different peripheral velocity from one another. As a result, the material is passed without interruption through two or more rolling mill stands which each apply shearing to the material across the entire thickness of the material. Therefore, using this device leads to considerable shearing of the material, with the associated advantages as described above.

10 This device according to the second aspect of the invention can also be used, in addition to the rolling of a slab, plate or strip consisting of a single metal or a single metal alloy, to roll a slab, strip or plate comprising two or more layers of metal, in which case the layers of metal may consist of the same metal alloy, of different metal
15 alloys or of different metals or metal alloys.

In this device, the difference in peripheral velocity is preferably at least 5% and at most 50%, and preferably at least 5% and at most 20%, for the same reasons as those explained above.

20 In this case too, it is preferable for the rolls of the rolling mill stand and the following rolling mill stands to have different diameters and/or to be driveable at different rotational speeds, as explained in connection with the first aspect of the invention.

25 According to an advantageous embodiment, in this case too, at least one of the one or more following rolling mill stands has a roll nip which is situated outside the plane of symmetry of the roll nip of the rolling mill stand, for similar reasons to those given in connection with the device according to the first aspect of the invention.

30 Also, in this case it is preferable for support rolls to be arranged upstream of the one or more following rolling mill stands, as seen in the direction of rolling, in order to support and/or guide the metal strip. This is for the same reasons as those which have been explained above.

35 It is preferable for feed means to be arranged upstream of the rolling mill stand, as seen in the direction of rolling, these feed means being designed to guide the strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls, preferably at an angle of between 10° and 25°

and more preferably between 15° and 25° , the feed means preferably comprising a feed surface or a roller table. This measure enables the rolls to gain a good grip on the material which is to be introduced.

- 5 The invention also relates to a slab, plate or strip produced using the above devices, the slab, plate or strip having a substantially uniform shearing over its thickness.

The metal is preferably aluminum or steel or stainless steel or copper or magnesium or titanium or one of their alloys. These are metals which are in industrial use, and it is
10 desirable for them to have good mechanical properties.

The invention will be explained below on the basis of an exemplary embodiment and with reference to the appended drawing, in which:

- 15 Figure 1 shows a highly diagrammatic illustration of an exemplary embodiment of a device according to the invention.

The figure shows an embodiment of the device 1 with a first rolling mill stand 11 and two following rolling mill stands 12, 13, diagrammatically indicated by a rectangle.
20 Each rolling mill stand has respective rolls 11a,b, 12a,b and 13a,b. Upstream of the first rolling mill stand 11 there is a feed surface 10 over which a slab of metal 2, for example of aluminum, can be supplied. The means for supplying the slab 2 and the means for driving the rolling mill stands are not shown; means of this type are known to the person skilled in this field.

25 In this exemplary embodiment, the rolling mill stands are arranged in such a manner that rolling mill stand 11 and 13 have a common plane of symmetry P which runs through the center of their respective roll nips. The plane Q through the center axes of the rolls 11a, 11b of the rolling mill stand 11 is perpendicular thereto, as is the plane T
30 through the center axes of the rolls 13a, 13b of the rolling mill stand 13.

The rolling mill stand 12 has a plane S passing through the center axes of its rolls 12a, 12b, which is likewise perpendicular to the plane P. The plane of symmetry R through the center of the roll nip of the rolling mill stand 12, however, is offset upward with
35 respect to the plane P. As a result, the slab 2 is passed at an angle to rolling mill stand 12 and then at an angle to rolling mill stand 13.

The feed surface 10 is at an angle α with respect to the plane P, α usually being

approximately 20°. The angle α is adjustable and can be matched to the type and thickness of the material.

5 Support and guide rolls 15a,b 16a,b, 17a,b and 18a,b are arranged between the rolling mill stands 11, 12 and 13 in order to guide the slab 2 to the rolling mill stands 12 and 13 after it has been rolled in rolling mill stand 11 and to support it over this path.

10 The rolls 11a and 11b have different diameters, so that, given an identical angular velocity, they have different peripheral velocities. The rolls 12a, 12b also have different diameters, but in this case the difference in size is reversed. This arrangement means that the shearing in the slab 2 as it passes through the rolling mill stands 11, 12 will have an inverted profile. The material which is displaced during passage through rolling mill stand 11 is, as it were, displaced back during passage through rolling mill stand 12.

15 In this exemplary embodiment, the rolling mill stand 13 has rolls 13a, 13b with an identical diameter. This stand rolls the slab 2 in the customary way, but it is also possible for the rolls 13a, 13b to be provided with a different rotational speed and therefore a different peripheral velocity. If the latter situation applies, the rolling mill stand 13 will also contribute to the shearing in the slab 2.

25 It will be clear that the device according to the invention can be used to roll slabs, plates and strips of different types of metal, such as steel, aluminum, stainless steel, copper, magnesium or titanium, and it is also possible to roll two or more slabs of metal resting on top of one another. The slabs may consist of different metals or different alloys from one another. If necessary, adjustments which lie within the scope of the person skilled in the art may be made to the device.

30 The device which has been described above and is illustrated in Figure 1 results in a slab, plate or strip being guided through and rolled by the device in the form of a coil. It will be clear that rolling mill stands may also be arranged in other ways with respect to one another, that it is possible to use more or fewer rolling mill stands and that the device can also be used only with rolling mill stand 11. The rolls may also optionally have different diameters and/or be driven at different angular velocities. The supporting and/or guiding of the slab, plate or strip can also be carried out using other means.

35 It is also possible for the feed surface 10 to be replaced by other feed means, such as a roller table, or a single feed roll for strip material, which feed roll has to be arranged in

such a manner that the strip material is passed into the roll nip of the rolling mill stand 11 at the angle α .

Another embodiment of the device according to the invention (not shown) is that in which the feed surface 10 is omitted and in which there are at least two rolling mill stands, for example rolling mill stand 11 and rolling mill stand 12, the rolls of these rolling mill stands having different peripheral velocities and the difference in peripheral velocity amounting to at least 5% and most 100%. The arrangement and further design of the rolling mill stands may be identical to that shown in Figure 1 and can be altered in a similar way.

The invention will be explained with reference to an exemplary embodiment.

Experiments were carried out using slabs of aluminum AA7050 with a thickness of 32.5 mm. These slabs were rolled once in a rolling device with two rolls, of which the top roll had a diameter of 165 mm and the bottom roll had a diameter of 135 mm. After rolling, the slabs had a thickness of 30.5 mm.

The slabs were introduced at different angles varying between 5° and 45°. The temperature of the slabs when they were introduced into the rolling device was approximately 450°C. The two rolls were driven at a speed of 5 revolutions per minute.

After rolling, the slabs had a certain curvature, which was highly dependent on the angle of introduction. The straightness of the slab after rolling can to a large extent be determined by the angle of introduction, in which context the optimum angle of introduction will be dependent on the degree of reduction in the size of the slab, the type of material and alloy, and the temperature. For the slabs of aluminum which have been rolled in the experiment described above, an optimum angle of introduction is approximately 20°.

A shear angle of 20° was measured in the slabs of aluminum which were rolled in accordance with the experiment described above. Using this measurement and the reduction in the size of the slab, it is possible to calculate an equivalent strain in accordance with the following formula:

$$\varepsilon_{eq} = \frac{2}{\sqrt{3}} \cdot \sqrt{(\varepsilon_{xx})^2 + (\varepsilon_{yy})^2}.$$

This formula is used to make it possible to present the strain in one dimension and is known from the book "Fundamentals of metal forming" by R.H. Wagoner and J.L. Chenot, John Wiley & Sons, 1997.

- 5 Therefore, in the slabs which have been rolled in accordance with the experiment, the equivalent strain is

$$\varepsilon_{eq} = \frac{2}{\sqrt{3}} \cdot \sqrt{\left(\ln \left(\frac{32.5}{30.5} \right) \right)^2 + \left(\frac{1}{2} (\tan 20^\circ) \right)^2} \approx 0.25 .$$

- 10 In the case of rolling with an ordinary roll, shearing does not take place across the thickness of the plate and the equivalent strain is therefore only

$$\varepsilon_{eq} = \frac{2}{\sqrt{3}} \cdot \sqrt{\ln \left(\frac{32.5}{30.5} \right)^2} \approx 0.07$$

- 15 (working on the basis of a uniform strain over the entire thickness of the plate).

Therefore, the rolling using the method according to the invention results in an equivalent strain which is three to four times higher than with conventional rolling without any difference in peripheral velocity. A high equivalent strain means less
 20 porosity in the slab, greater recrystallization and therefore greater grain refinement, and more extensive breaking up of the second-phase particles (constituent particles) in the slab. These effects are generally known to the person skilled in this field of engineering if the equivalent strain increases. Therefore, the rolling according to the invention means that the resulting properties of the material are greatly improved as a result of
 25 the use of the method according to the invention.

CLAIMS

1. A device for processing a metal slab, plate or strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being
5 designed to roll a metal slab, plate or strip between the rolls, characterized in that the device is provided with feed means which are designed to guide the slab, plate or strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls.
- 10 2. The device as claimed in claim 1, in which the feed means are designed to guide the slab, plate or strip between the rolls at an angle of between 10° and 25° with respect to the perpendicular to the plane through the center axes of the rolls, preferably at an angle of between 15° and 25°, and more preferably at an angle of substantially 20°.
- 15 3. The device as claimed in claim 1 or 2, in which the feed means comprise a feed surface or a roller table.
4. The device as claimed in one of the preceding claims, in which the angle between
20 the feed means and the rolling mill stand is adjustable.
5. The device as claimed in one of the preceding claims, in which the rolling mill stand is designed in such a manner that, during use, the rolls have different peripheral velocities, the difference in peripheral velocity amounting to at least
25 5% and at most 100%, and preferably at least 5% and at most 50%, and more preferably at least 5% and at most 20%.
6. The device as claimed in claim 5, in which the rolls have a different diameter and/or can be driven at different rotational speeds.
- 30 7. The device as claimed in one of the preceding claims, in which the device is provided with one or more following rolling mill stands with driveable rolls which are positioned downstream of the rolling mill stand, as seen in the rolling direction.
- 35 8. The device as claimed in claim 7, which is designed to feed the metal slab, plate or strip, during use, at an angle of between 5° and 45°, to at least one of the one or more following rolling mill stands, preferably at an angle of between 10° and

25°, and more preferably between 15° and 25°, the angle preferably being adjustable.

- 5 9. The device as claimed in claim 7 or 8, in which at least one of the one or more following rolling mill stands is designed in such a manner that, during use, the rolls have different peripheral velocities, the rolls preferably having a different diameter and/or it being possible for the rolls to be driven at different rotational speeds.
- 10 10. The device as claimed in claim 7, 8 or 9, in which at least one of the one or more following rolling mill stands has a roll nip which is situated outside the plane of symmetry of the roll nip of the rolling mill stand.
- 15 11. The device as claimed in claim 7, 8, 9 or 10, in which support rolls are arranged upstream of the one or more following rolling mill stands, as seen in the rolling direction, in order to support and/or guide the metal slab, plate or strip.
- 20 12. The device as claimed in one of claims 1 – 6, which is provided on both sides with feed means which are designed to pass the slab, plate or strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls, preferably at an angle of between 10° and 25°, the angle between the feed means being adjustable between 0 and 45° and it being possible for the rolls to be driven in both directions of rotation.
- 25 13. A device for processing a metal strip, comprising a rolling mill stand with a roll nip between two driveable rolls, the rolling mill stand being designed to roll the metal strip between the rolls, characterized in that the device is provided with one or more following rolling mill stands with driveable rolls, and in that the rolling mill stand and one or more following rolling mill stands are designed in such a
30 manner that, during use, their rolls have different peripheral velocities, the difference in peripheral velocity amounting to at least 5% and at most 100%.
14. The device as claimed in claim 13, in which the difference in peripheral velocity is at least 5% and at most 50%, and preferably at least 5% and at most 20%.
- 35 15. The device as claimed in claim 13 or 14, in which the rolls of the rolling mill stand and the following rolling mill stands have a different diameter and/or can be driven at different rotational speeds.

16. The device as claimed in claim 13, 14 or 15, in which at least one of the one or more following rolling mill stands has a roll nip which is situated outside the plane of symmetry of the roll nip of the rolling mill stand.
- 5 17. The device as claimed in one of claims 13 – 16, in which support rolls are arranged upstream of the one or more following rolling mill stands, as seen in the rolling direction, in order to support and/or guide the metal strip.
- 10 18. The device as claimed in one of claims 13 - 17, in which feed means are arranged upstream of the rolling mill stand, as seen in the rolling direction, which feed means are designed to pass the strip between the rolls at an angle of between 5° and 45° with respect to the perpendicular to the plane through the center axes of the rolls, preferably at an angle of between 10° and 25°, and more preferably
15 between 15° and 25°, the feed means preferably comprising a feed surface or a roller table.
19. A metal slab, plate or strip produced using the device as claimed in one of claims 1 – 12, the slab, strip or plate having a substantially uniform shearing over its
20 thickness.
20. A metal strip produced using the device as claimed in one of claims 13 – 18, the strip having a substantially uniform shearing over its thickness.
- 25 21. The metal slab, plate or strip as claimed in claim 19 or 20, in which the metal is aluminum or steel or stainless steel or copper or magnesium or titanium or one of their alloys.

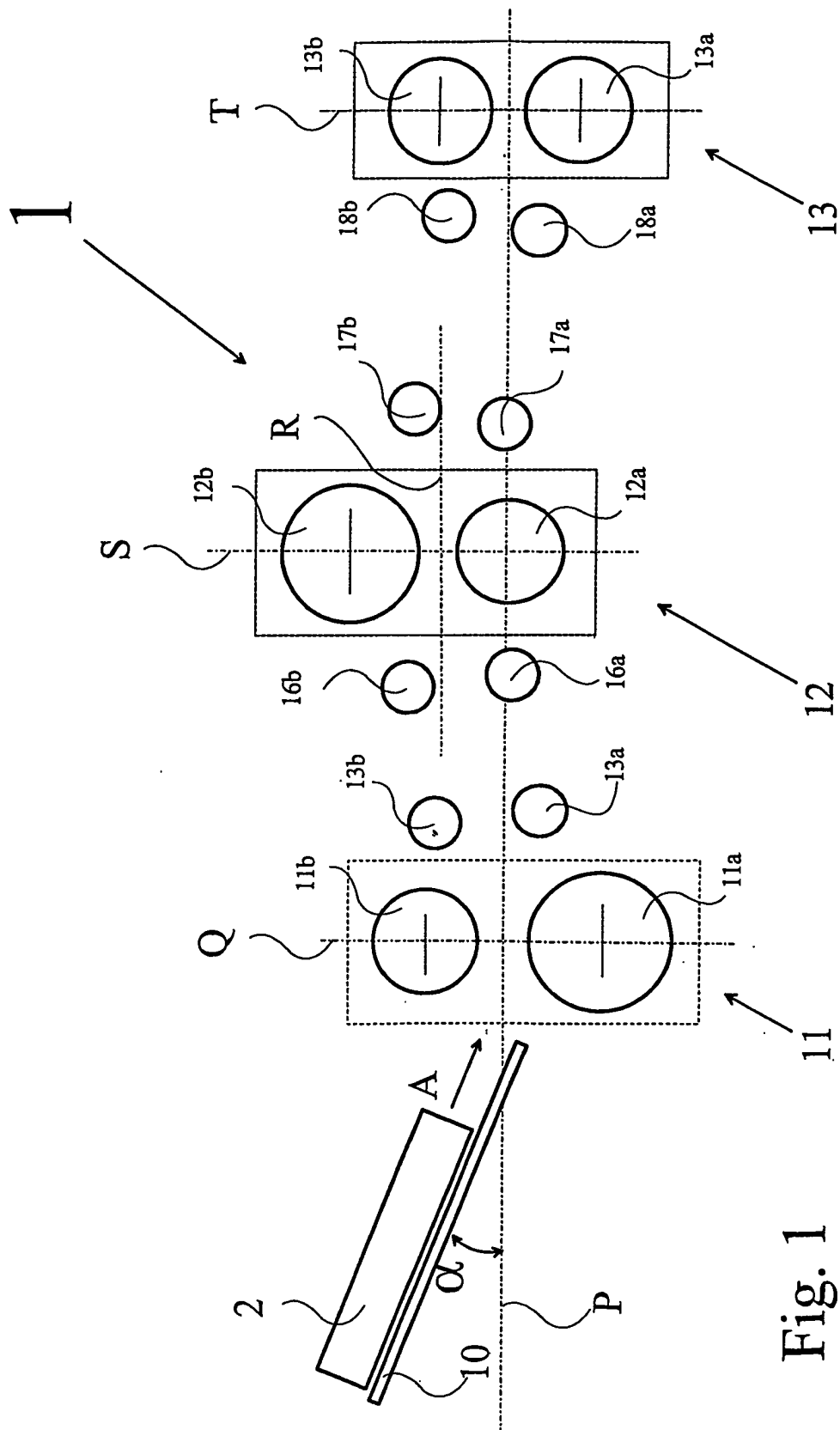


Fig. 1